



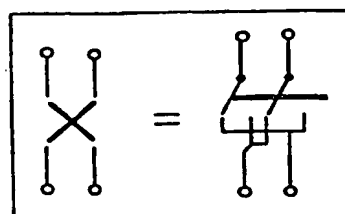
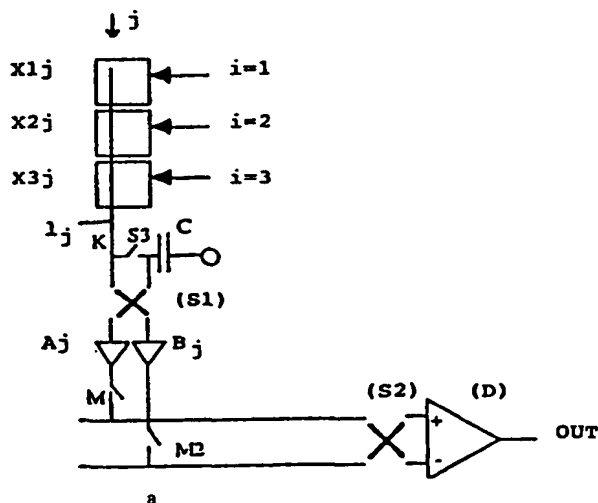
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : H04N 3/15, 5/217		A1	(11) International Publication Number: WO 99/16238
			(43) International Publication Date: 1 April 1999 (01.04.99)
(21) International Application Number: PCT/BE98/00139		(81) Designated States: AL, AU, BA, BB, BG, BR, CA, CN, CU, CZ, DE, DE (Utility model), EE, GD, GE, HR, HU, ID, IL, IS, JP, KP, KR, LC, LK, LR, LT, LV, MG, MK, MN, MX, NO, NZ, PL, RO, SG, SI, SK, SL, TR, TT, UA, US, UZ, VN, YU, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 22 September 1998 (22.09.98)		Published With international search report.	
(30) Priority Data: 97870143.1 22 September 1997 (22.09.97) EP 97870170.4 24 October 1997 (24.10.97) EP			
(71) Applicant (for all designated States except US): INTERUNIVERSITAIR MICRO-ELEKTRONICA CENTRUM [BE/BE]; Vereniging Zonder Winstbejag, Kapeldreef 75, B-3001 Heverlee (BE).			
(72) Inventors; and (75) Inventors/Applicants (for US only): DIERICKX, Bart [BE/BE]; Cornelis Deherdstraat 8, B-2640 Molsel (BE). KAVADIAS, Spyros [GR/BE]; Predikherinnenstraat 6, B-3000 Leuven (BE).			
(74) Agents: VAN MALDEREN, Joëlle et al.; Office Van Malderen, Place Reine Fabiola 6/1, B-1083 Brussels (BE).			

(54) Title: DEVICES AND METHODS FOR IMPROVING THE IMAGE QUALITY IN AN IMAGE SENSOR

## (57) Abstract

The present invention is related to an image sensor comprising an array of rows ( $i$ ) and columns ( $j$ ) of pixels ( $X_{ij}$ ), all the pixels of one column of the array being connected to at least one common pixel output line ( $l_j$ ) having at least one memory element ( $M_j$ ) and at least a first amplifying element ( $A_j$ ), all these amplifying elements ( $A_j$ ) being connected to a common output amplifier ( $D$ ). According to one preferred embodiment, said image sensor comprises: a second amplifying element ( $B_j$ ) on the output of the memory element ( $M_j$ ); said common output amplifier ( $D$ ) having at least two input terminals; means ( $S1$ ) for switching the pixel's signal on the common output line ( $l_j$ ) and the memory element's signal ( $M_j$ ) to respectively third and second amplifying element ( $A_j$  and  $B_j$ ) of one column; and means ( $S2$ ) for switching the two output signals of the amplifying elements ( $A_j$ ,  $B_j$ ) of one column to respectively first and second input terminals of said common output amplifier ( $D$ ).



**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

5

DEVICES AND METHODS FOR IMPROVING THE IMAGE QUALITY IN AN  
IMAGE SENSOR

10

Field of the invention

The present invention relates to solid state imaging devices being manufactured in a CMOS- or MOS-technology.

15

More particularly, the principal object of the present invention is related to methods and devices which are able to improve the image quality in an image sensor.

Another object of the present invention is related to the improvement of the image quality by a method of correcting isolated pixel values present in an image taken by imaging devices.

Background of the invention

25

Solid state image sensors are well known. Virtually all solid-state imaging sensors have as key element a photosensitive element being a photoreceptor, a photo diode, a photo transistor, a CCD gate, or alike. Typically, the signal of such a photosensitive element is a current which is proportional to the amount of electromagnetic radiation (light) falling onto the photosensitive element.

30

A structure with a photosensitive element included in a circuit having accompanying electronics is

called a pixel. Such pixel can be arranged in an array of pixels so as to build focal plane arrays of rows and columns.

Commonly such solid state image sensors are  
5 implemented in a CCD-technology or in a CMOS- or MOS-  
technology. Solid state image sensors find a widespread use  
in devices such as camera systems. In this application a  
matrix of pixels comprising light sensitive elements  
constitutes an image sensor, which is mounted in the camera  
10 system. The signal of said matrix is measured and  
multiplexed to a so-called video-signal.

Of the image sensors implemented in a CMOS-  
or MOS-technology, CMOS or MOS image sensors with passive  
pixels and CMOS or MOS image sensors with active pixels are  
15 distinguished. An active pixel is configured with means  
integrated in the pixel to amplify the charge that is  
collected on the light sensitive element. Passive pixels do  
not have said means and require a charge sensitive  
amplifier that is not integrated in the pixel. For this  
20 reason, active pixel image sensors are potentially less  
sensitive to noise fluctuations than passive pixels. Due to  
the additional electronics in the active pixel, an active  
pixel image sensor may be equipped to execute more  
sophisticated functions, which can be advantageous for the  
25 performance of the camera system. Said functions can  
include filtering, operation at higher speed or operation  
in more extreme illuminations conditions.

Examples of such imaging sensors are  
disclosed in EP-A-0739039, in EP-A-0632930 and in  
30 US-A-5608204. The imaging devices based on the pixel  
structures as disclosed in these patent applications  
however are still subject to deficiencies in the image  
quality of the devices.

A problem in these CMOS based imaging devices appears because material imperfections and technology variations have as effect that there is a non-uniformity in the response of the pixels in the array. This effect is  
5 caused by a non-uniformity or fixed pattern noise (FPN) or by a photoresponse non-uniformity (PRNU). Correction of the non-uniformity needs some type of calibration, e.g. by multiplying or adding/subtracting the pixel's signals with a correction amount that is pixel-dependent.

10 Several methods to cancel FPN are based on techniques that are often called correlated double sampling or offset compensation. The methods in general are based on the following: the signal of the pixel is subtracted from the signal of the same pixels in a reference state (this  
15 reference state is typically the reset or dark state). The difference of both signal is free of pixel-related non-uniformity. However, if the differencing circuit is common for a part of the imager (typically, common for one column), a new non-uniformity will originate due to the  
20 non-uniformity of the differencing circuits. In a typical APS imager with common column buffers or column amplifiers, the new fixed pattern noise is column dependent, and is visible in the image as a shade of vertical stripes.

A stripe-shaped FPN is much more annoying  
25 than a pure statistical FPN. It is seen in experiments that a true random FPN of 5% RMS is barely visible to the human eye, whereas a stripe-shaped FPN remains visible even when the amplitude is below 1% RMS. The reason is that the human eye has a kind of built-in spatial filter that recognises  
30 larger structures even when they have low contrast.

Even if in the case that we have no fixed pattern noise, the photoresponse non-uniformity can be different from 0.

Another problem arises due to processing imperfections, statistics, etc. This means that typically, a finite number of pixels in a pixel array will be defective (hard faults) or yield a signal that deviates  
5 visibly from the "exact" pixel value. Such faults appear as white or black (or grey) points in the image. This class of faults in the sequel is called an isolated pixel value.

A known way to cancel these spots is to store a list of them and of their positions in the image in a  
10 memory unit in the device. In an image processing step, the isolated pixel value is then replaced by e.g. the average of the surrounding pixels. This method is viable, but has the disadvantage that it requires a memory. Moreover, it cannot handle isolated pixel values that appear  
15 intermittently or only in certain cases. A good example, is a so-called dark current pixel. Such pixels will appear white in a dark environment, but will behave normal in a bright environment.

Other ways to cancel isolated pixels faults  
20 have been proposed, e.g. the spatial median filter or other types of Kalman filters can be used to remove such isolated faults. Unfortunately, such filters do also remove useful detail from the image. Consider the image of a star covered sky with an image sensor that has some faulty pixels that  
25 appear white. The quoted filters are not able to remove the white point due to faults, and leave the white points that are stars untouched.

#### Aim of the invention

30 The present invention aims to suggest a pixel structure and methods to improve the image quality, more in particular the image non-uniformity of in array of pixels by cancellation of the appearance of column-shaped fixed pattern noise (FPN).

Main characteristics of the present invention

As a first object, the present invention is related to an image sensor comprising an array of rows and columns of pixels, all the pixels of one column of the  
5 array being connected to at least one common pixel output line having at least one memory element and at least a first amplifying element, all these amplifying elements being connected to a common output amplifier.

According to one preferred embodiment, the  
10 image sensor further comprises :

- a second amplifying element on the output of the memory element,
- said common output amplifier having at least a first and a second input terminals,
- 15 - means for switching the pixel's signal on the common output line and the memory element's signal to respectively first and second amplifying elements of one column, and
- means for switching the two output signals of the  
20 amplifying elements of one column to respectively first and second input terminals of said common output amplifier.

Preferably, the switching means comprise at least one cross-bar switch.

25 According to another preferred embodiment, the image sensor further comprises before the amplifying element two parallel circuits being connected through switches to the common pixel output line, at least one circuit having said memory element. Preferably, both  
30 circuit have a memory element.

According to another preferred embodiment, said common pixel output line is being connected through switches to said memory element and said amplifying

element, where the offset of the amplifying element is stored on the memory element during a first phase of the read-out, and this offset is subtracted from the signal of the amplifying element during the second phase of the read-out.

The present invention is also related to a method of reading out an array of rows and columns of pixels in an image sensor as described hereabove according to the first embodiment, comprising the steps of:

- 10 - amplifying the output signals of essentially each pixel of one column in the first amplifying element thereby obtaining a set of amplified pixel output signals,
- amplifying the reference signals of essentially each pixel of one column in the second amplifying element,
- 15 thereby obtaining a set of amplified pixel reference signals,
- consecutively, for essentially each pixel of said column imposing the amplified pixel output signal to a first or a second terminal of said common output amplifier and
- 20 imposing the amplified pixel reference signal to a second or a first terminal of said common output amplifier, while switching the amplified pixel output signal to respectively said first and said second terminals for essentially each consecutive pixel of said
- 25 column, said reference signal being imposed to the other terminal of said common output amplifier.

A voltage can be imposed to a node. In this case, it means e.g. that the node is connected to a voltage source. The voltage source should be higher than the node, i.e. it should have a lower impedance.

According to another preferred embodiment, the present invention is related to a method of reading out an array of rows and columns of pixels in an image sensor



as described hereabove in the second embodiment of the present invention, comprising the steps of :

- sampling the signal in a first phase and storing it in a memory element,
- 5 - sampling the signal in a second phase and possibly storing it in another memory element,
- subtracting said first signal from said second signal in a unique output circuit.

According to another preferred embodiment,  
10 the present invention is related to a method of reading out an array of rows and columns of pixels in an image sensor as described in the third embodiment of the present invention, comprising the steps of :

- during a first phase, calibrating the output of the  
15 amplifying element to a predetermined value,
- storing said value in a memory element during the application of a first signal of said pixel on the line,
- during a second phase, applying a second signal of said pixel on the line in order to have on the output a signal  
20 proportional to the difference between first and second signals.

Another aspect of the present invention is related to a method of replacing an isolated pixel value in the image of an image sensor, being an array of pixels, and  
25 wherein at least one current source is connected to the pixels, the method comprising the step of :

- limiting said isolated pixel value between or to an upper and/or a lower bound that is derived from the values of pixels in the immediate neighbourhood of the  
30 said isolated pixel value.

Preferably, said upper and/or lower bounds are found by extrapolating the immediate neighbourhood pixel values towards a value that corresponds to the

position of said individual pixel in relation to the immediate neighbourhood pixels.

Said upper and/or lower bounds are found by extrapolating the values of a neighbour ( $V_1N$ ) of the pixel having said isolated pixel value and of the neighbour thereafter ( $V_2N$ ), the replacing pixel value being calculated as  $V_1N + n * (V_1N - V_2N)$ ,  $n$  being a real number.

The neighbourhood and the neighbourhood thereafter are on the same row of said array. Preferably, the upper bound is the maximum of a set of values, said set being determined as the pixel values ( $a, b, c, d, e$ ) of pixels on the same row of said array as said isolated pixel, said upper bound being calculated as

$c_{max} = F(a, b, c, d)$ , or  $c_{max} = G(E(a, b), E(e, d), E(b), E(d))$

where  $F$  is a non-linear or linear function,  $G$  is a non-linear GE or linear function,  $E$  is an extrapolating function, wherein  $c_{max} = \text{MAX}(2b - a, 2d - e, b, d)$  together with

$c_{min} = \text{MIN}(2b - a, 2d - e, b, d)$

with  $\text{MAX}()$  yielding the maximum, respectively the minimum of the arguments, the corrected  $c$ -value being obtained as

$c = \text{MIN}(\text{MAX}(c, c_{min}), c_{max})$ .

## 25 Brief description of the drawings

Figure 1a represents a particular implementation of a column FPN cancellation method and the corresponding image sensor structure therefor.

30 Figure 1b represents an embodiment of a cross-bar switch used in the structure represented in Fig. 1a.

- Figure 2 describes another particular implementation of a column FPN cancellation method and the corresponding image sensor structure therefor.
- 5 Figure 3 describes a particular embodiment of an output block being used in the structure as represented in Fig. 2.
- Figure 4 represents the switching diagram for the read-out signal applied to the several  
10 switches in the structure as represented in Fig. 2.
- Figures 5 represent another particular implementation of a column FPN cancellation method and the corresponding image sensor structure  
15 therefor, wherein Fig. 5a represents more particularly one column in an array of pixels being connected to two different structures represented in details in Fig. 5b and 5c during a first phase and a second phase.
- 20 Figure 6 represents the specific topology used for the structure represented in Fig. 5b and 5c.
- Figure 7 represents the switching diagram for the read-out sequence to the several switches used in the structure represented in Fig. 6.
- 25 Figures 8a and 8b represent a method of correcting isolated white pixel values being present in an image composed by an array of pixels.

30 Brief description of preferred embodiments of the present invention

As a first object of the present invention, a first structure of an APS image sensor is represented in Fig. 1. References  $(X_{1j})$ ,  $(X_{2j})$  and  $(X_{3j})$  are three pixels

of a column of an image sensor. The pixel's signal on a common output line ( $l_j$ ) is represented in particular by the column bus "K" in the present case and is fed to the optional buffer amplifier  $A_j$ , and/or stored on a memory element (capacitor C + switch S3), and fed to amplifier  $B_j$ . By the relative timing of the addressed pixel's reset pulse and the control of the switch S3, one can make that the pixel's signal and its reference level are available on amplifiers  $A_j$ , reps.  $B_j$ . The fact that the signal passes through the column amplifiers  $A_j$  and  $B_j$ , is a source of offset non-uniformity, which is column related and causes a vertical stripe-shaped FPN. More specifically, each column will feature an average "OV" offset voltage referred to the average of the other columns.

Switches (S1) and (S2) are crossbar switches. Suppose that they are in the forward direction either in crossed directions. Both switches S1 and S2 operate synchronously. In both cases, the signal on the capacitor C goes to the input of the output amplifier, and the signal on K goes to the + input of the output amplifier. Yet, the "OV" of the column will be positive in the one case and negative in the other case. Since the switches (S1)/(S2) are modulated, e.g. essentially turned direction at each new row ( $i = 1, 2, 3$ ) of the image, the average offset of a column will be zero. For each individual pixel of a column, there will be indeed remain an offset which is + or - OV but this is a very small feature, and is not recognised by the eye as a stripe.

Another embodiment of the present invention is to suggest a read-out scheme for image sensors that suppresses the effects of non-uniformities caused by variations in pixels as well as variations in the output amplifiers. This read-out scheme can be used in sensors

that provide the output signal in terms of a difference. For example, in a sensor with integrating pixels, this difference is the voltage between the output when the pixel is on reset state and the output voltage after integration  
5 time.

Namely the method suggests to subtract the signal when a pixel is reset from the signal after the integration time, in order to have a signal which is free from pixel variations. In order to avoid the introduction  
10 of the non-uniform column amplifiers effects, the signal of the reset state as well as the signal after integration are sampled and held by the column read-out circuit. Finally, the subtraction is being carried out by a unique subcircuit at the sensor's output (D). This is detailed in Fig. 2.

15 For every row of pixels the read-out process is, of course, identical. Let us assume that the  $i^{\text{th}}$  row is selected. When pixels are reset, the switches controlled by the signal  $\Phi_1$ , are closed, thus the reset-level output of every pixel on the  $i^{\text{th}}$  row, namely  $x'_{ij}$ , is stored on the  
20 corresponding memory element  $M_{Rj}$  (which is in the present case a capacitor).

Then, the switches  $S4_j$  controlled by  $\Phi_1$  are opened and pixels start integrating the charge carriers produced by the impinging light. After the lapse of the  
25 integration time, the switches  $S5_j$  controlled by  $\Phi_2$  are closed, thus storing the values of the pixel output to the memory element  $M_{Sj}$  (also a capacitor). This value, for the pixel with coordinates  $ij$  is denoted as  $x_{ij}'$ .

After the sample and hold phase for the two  
30 voltages,  $x'_{ij}$  and  $x_{ij}'$ , for the first column and by proceeding from the first column to the last, the

appropriate column read-out circuit is connected with the output.

When the  $i^{\text{th}}$  column has been selected, the signal  $\Phi 3$  drives the switch  $S6_j$  to led the signal  $x'_{ij}$  to  
 5 the output modified according to the action of the column amplifier, so as a signal

$$y'_{ij} = A_j x'_{ij} + B_j \quad (1)$$

is led to block D (common output amplifier).

The block D is an easily realisable circuit  
 10 with an output

$$z(n) = [y(n) - y(n-1)] \quad (2)$$

where  $y(n)$  denotes the input as instant  $n$ .

A preferred embodiment of such output block (D) is described in details in Fig. 3. Therefore, the  
 15 output signal will be free from variations in the characteristics of pixels and the column amplifiers.

$$y'^r_{ij} - y'^s_{ij} = A_j (x'^r_{ij} - x'^s_{ij}) \quad (3)$$

where  $A_j$  is easily reproducible, by example by using source followers as the local final phase of the column circuits  
 20 (when  $A_j = 2$ ,  $B_j = -V_{thj}$ ).

Fig. 4 shows a switching diagram for the above-mentioned read-out circuit wherein  $\Phi 3$  is controlling  $S4_j$ ,  $\Phi 4$  is controlling the switch  $S5_j$  and  $\Phi 5$  is controlling the switch  $S6_j$ .

25 According to another embodiment of the present invention, an attempt to overcome the problem of offset introduced by the column in a image sensor consisting of pixels is described in Figs. 5 & 6, which can be used with pixels that are read-out twice in every  
 30 access. For example, in integrating pixels, one read

operation is being performed when the pixel is set on the reset phase (first phase) and the second read-out moment is after a certain integration time (second phase), the first phase is defined by a period wherein the read-out signal of the pixel is according a first state while the second phase is defined by a period such as an integration period where the read-out signal of the pixel is in another state.

In the first phase, when pixel output is  $V_1$ , the capacitor  $C$  stores a charge :

$$10 \quad Q = C(V_{ac} - V_{out}) = C(V_{ac} - V_1 + V_{th}) \quad (4)$$

where  $V_{th}$  is the threshold voltage of  $\mu$ .

During second phase, when pixel output is  $V_2$ , the capacitor stores again charge  $Q$  which now can be expressed as :

$$15 \quad Q = C(V_{g\mu} - V_2) \quad (5)$$

where  $V_{g\mu}$  is the gate voltage of  $\mu$ .

From (4) and (5), we obtain :

$$V_{g\mu} = V_2 - V_1 + V_{ac} + V_{th} \quad (6)$$

Therefore :

$$20 \quad V_{out} = V_2 - V_1 + V_{ac} \quad (7)$$

i.e. the output voltage does not depend on the  $V_{th}$  (where variations in the  $V_{th}$  cause offsets in the signal  $V_{out}$ ).

The column amplifier can be implemented by using the topology described in details in Fig. 6.

25 Switches  $S_7$ ,  $S_8$ ,  $S_9$ ,  $S_{10}$  and  $S_{11}$  are being controlled by signals  $\Phi_5$  and  $\Phi_6$  (when  $\Phi_i$  is high, the corresponding switches are closed) as represented in Fig. 7.

According to a preferred embodiment represented in Fig. 7,  $S_7$ ,  $S_8$  and  $S_9$  are controlled by  $\Phi_5$  while  $S_{10}$  and  $S_{11}$  are controlled by  $\Phi_6$  (when  $\Phi_i$  is high, the corresponding switches are closed). This means that  $\Phi_5$

is describing the situation represented in Fig. 5b while  $\Phi 6$  is representing the situation represented in Fig. 5c.

According to another aspect, the present invention is able to discriminate between isolated pixel faults and features in the real image. In the case of an image of a star covered sky, it should be noted that the fact that the image projected through a lens is never perfectly sharp. Even with good lenses, a star image is not projected on a single pixel. Always the point like source of the star will be smeared out over a central pixel and a few neighbours. In a 1-dimensional cross section, a star image will look like the image in Fig. 8a, while an isolated pixel fault will look like in Fig. 8b.

In the above simple example, the peak in Fig. 8b should be removed, while the peak in 8a should remain untouched.

The advantage is clear, only device faults are corrected while normal images are left untouched. The operation causes no visible image degradation in faultless parts of the image.

According to this second aspect of the present invention, a method to remove an isolated whiter or darker pixel from the image is suggested. This method consists in limiting the value of every individual pixel between an upper and/or a lower bound that is/are derived from the values of pixels in the intermediate neighbourhood of the said pixel.

Preferably, the upper and/or lower bounds are found by extrapolation of the neighbourhood pixel values towards the position of the said individual pixel. The upper and/or lower bound are/is a combination of one or several such 1-D or 2-D extrapolations done with different



methods, and/or from different sides of the said individual pixel.

Preferably, extrapolation is the linear extrapolation of a neighbour (N1) of the said individual pixel (IP) and the neighbour thereafter (N2). The extrapolated value is calculated as  $2*N1-N2$  or more general:  $N1 + n * (N1-N2)$  where the parameter  $n$  is a real number, typically between 0 and 3.

According to another preferred embodiment, the calculation of the upper bounds is performed by extrapolating values from the two sides of said individual pixels. The advantage is that only the pixels data in 1 line of an image are required, which saves memory and operations and allows straightforward implementation as a pipelined filter. Also such a filter is able to correct a vertical line defect.

In the example of Figs. 8a and 8b, five pixels in a neighbourhood (a 5-pixel "kernel") are taken. The experience is that smaller kernels do not yield good results. Larger kernels may give some improvements compared to the 5-pixel kernel.

CLAIMS

1. An image sensor comprising an array of rows (i) and columns (j) of pixels ( $X_{ij}$ ), all the pixels of one column of the array being connected to at least one  
5 common pixel output line ( $l_j$ ) having at least one memory element ( $M_j$ ) and at least a first amplifying element ( $A_j$ ), all these amplifying elements ( $A_j$ ) being connected to a common output amplifier (D), characterised in that the sensor further comprises:
- 10 - a second amplifying element ( $B_j$ ) on the output of the memory element ( $M_j$ ),  
- said common output amplifier (D) having at least two input terminals,  
- means (S1) for switching the pixel's signal on the common  
15 output line ( $l_j$ ) and the memory element's signal ( $M_j$ ) to respectively third and second amplifying elements ( $A_j$  and  $B_j$ ) of one column, and  
- means (S2) for switching the two output signals of the  
20 amplifying elements ( $A_j$ ,  $B_j$ ) of one column to respectively first and second input terminals of said common output amplifier (D).
2. An image sensor as recited in claim 1, wherein said switching means comprise at least one cross-bar switch.
- 25 3. An image sensor comprising an array of columns and rows of pixels ( $X_{ij}$ ), all the pixels of one column of the array being connected to at least one common pixel output line ( $l_j$ ) having at least one memory element ( $M_j$ ) and at least one amplifying element ( $A_j$ ), all these  
30 amplifying elements ( $A_j$ ) being connected to a common output amplifier (D), characterised in that before the amplifying

element ( $A_j$ ), the common pixel output line ( $l_j$ ) is divided through switches ( $S4_j$  and  $S5_j$ ) in two parallel circuits, at least one circuit having said memory element ( $M_j$ ).

4. An image sensor as recited in claim 3,  
5 wherein both circuits have a memory element ( $M_{sj}$  and  $M_{rj}$ ).

5. An image sensor comprising an array of columns and rows of pixels ( $X_{ij}$ ), all the pixels of one column of the array being connected to at least one common pixel output line ( $l_j$ ) having at least one memory element  
10 ( $M_j$ ) and at least one amplifying element ( $A_j$ ), all these amplifying elements ( $A_j$ ) being connected to a common output amplifier ( $D$ ), characterised in that said common pixel output line ( $l_j$ ) is being connected through switches ( $S7_j$ ,  $S8_j$ ,  $S9_j$  and  $S10_j$ ,  $S11_j$ ) to a memory element ( $C_j$ ) and an  
15 amplifying element ( $\mu_j$ ), where the offset of the amplifying element is stored on the memory element during a first phase of the read-out, and this offset is subtracted from the signal of the amplifying element during the second phase of the read-out.

20 6. A method of reading out an array of rows and columns of pixels ( $X_{ij}$ ) of an image sensor according to claim 1, comprising the steps of :

- amplifying the output signals of essentially each pixel of one column in the first amplifying element ( $A_j$ )  
25 thereby obtaining a set of amplified pixel output signals,
- amplifying the reference signals of essentially each pixel of one column in the second amplifying element ( $B_j$ ), thereby obtaining a set of amplified pixel  
30 reference signals,
- consecutively, for essentially each pixel ( $i = 1, 2, 3$ )

of said column imposing the amplified pixel output signal to a first or a second terminal of said common output amplifier (D) and imposing the amplified pixel reference signal to a second or a first terminal of said common output amplifier (D), while switching the amplified pixel output signal to respectively said first and said second terminals for essentially each consecutive pixel of said column, said reference signal being imposed to the other terminal of said common output amplifier.

7. A method of reading out an array of rows and columns of pixels ( $X_{ij}$ ) of an image sensor as recited in claim 3, comprising the steps of :

- sampling the signal in a first phase and storing it in a memory element ( $M_{ij}$ ),
- sampling the signal in a second phase and possibly storing it in another memory element,
- subtracting said first signal from said second signal in a unique output circuit (D).

8. Method as recited in claim 7, wherein said first phase is the reset phase and said second phase is after the integration period.

9. A method of reading out an array of rows and columns of pixels ( $X_{ij}$ ) of an image sensor as recited in claim 5, comprising the steps of :

- during a first phase, calibrating the output of the amplifying element to a predetermined value,
- storing said value in a memory element during the application of a first signal of said pixel on the line,
- during a second phase, applying a second signal of said pixel on the line in order to have on the output a signal proportional to the difference between first and second signals.

1/6

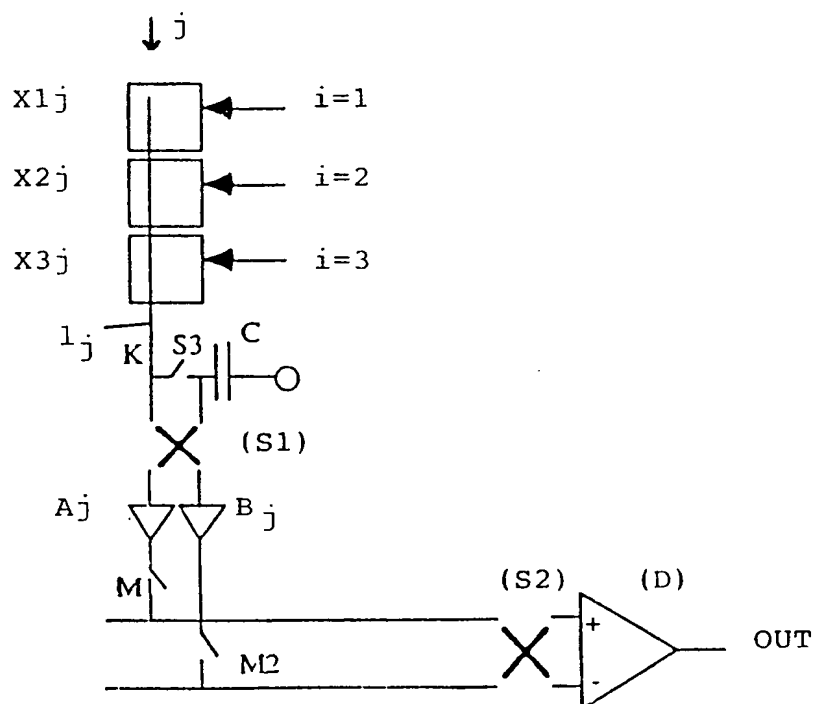


FIG. 1a

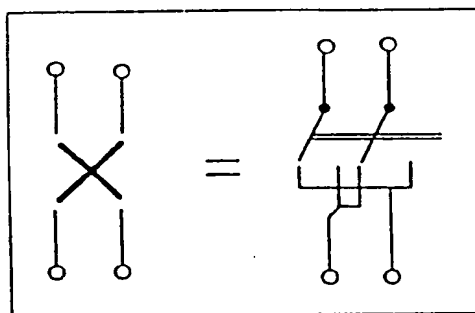


FIG. 1b

This Page Blank (uspte)

2/6

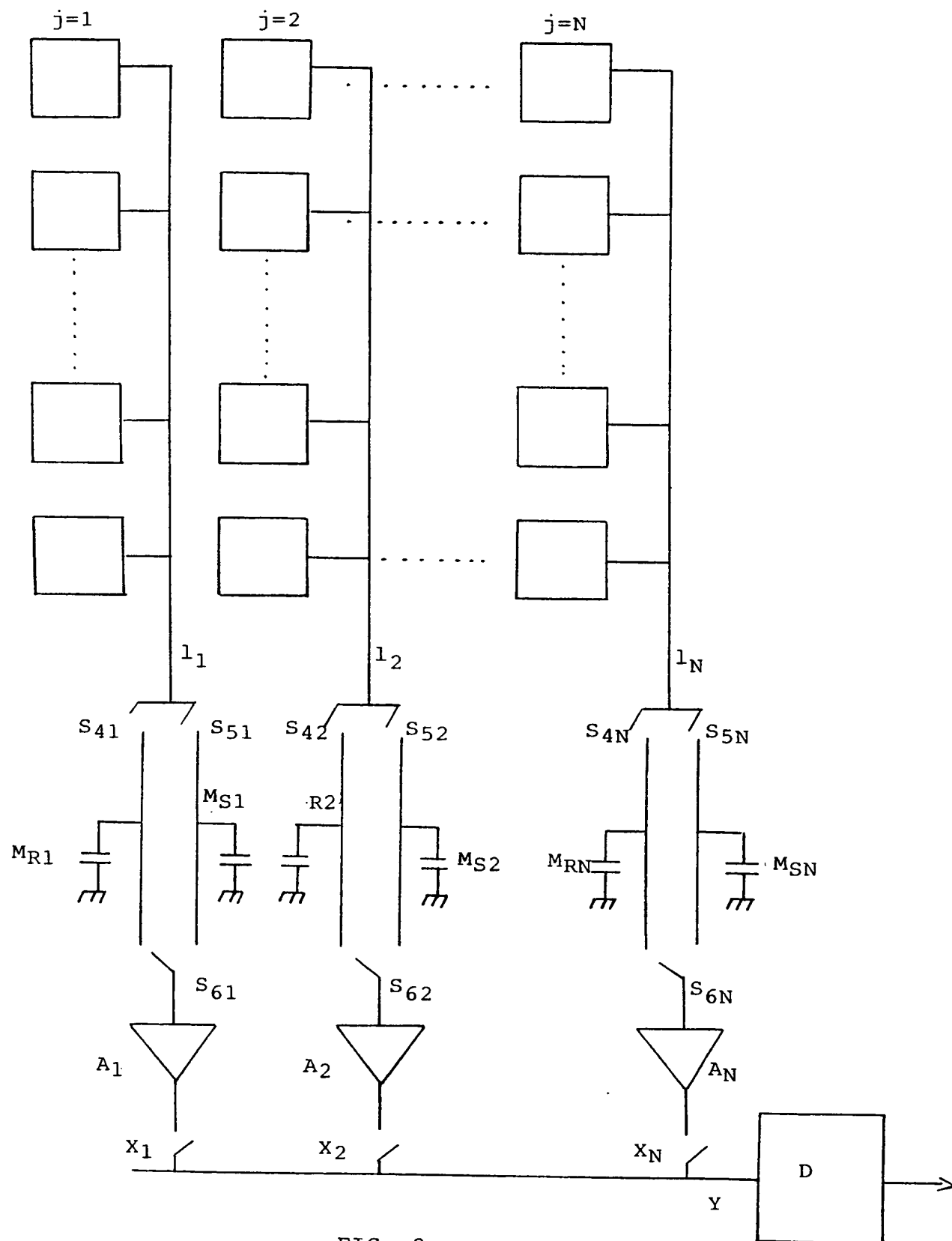


FIG. 2

This Page Blank (uspto)



3/6

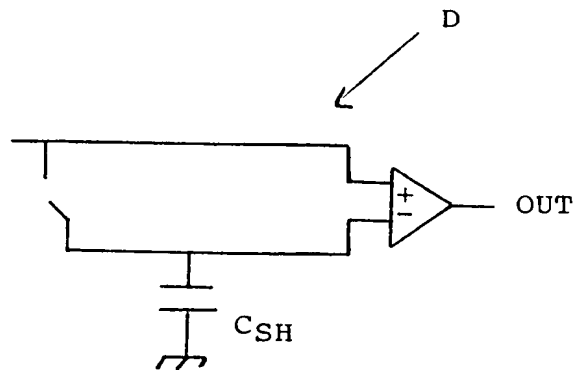


FIG. 3

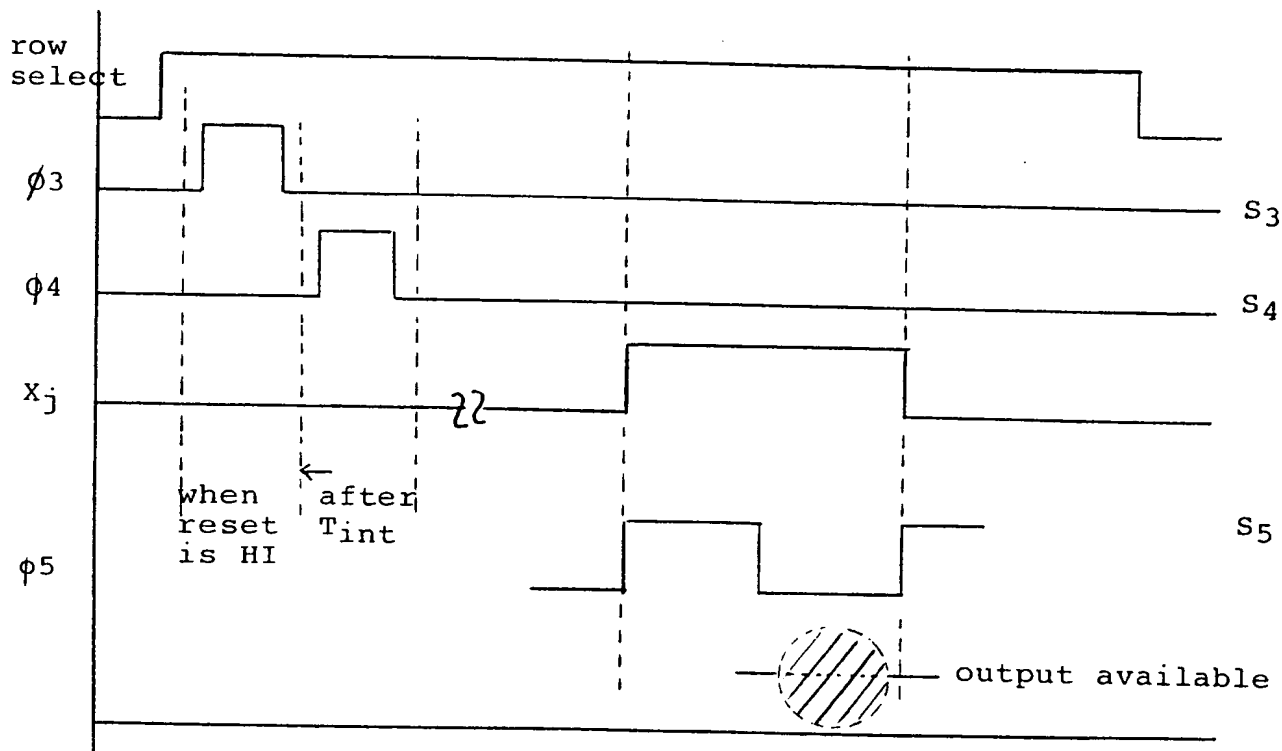
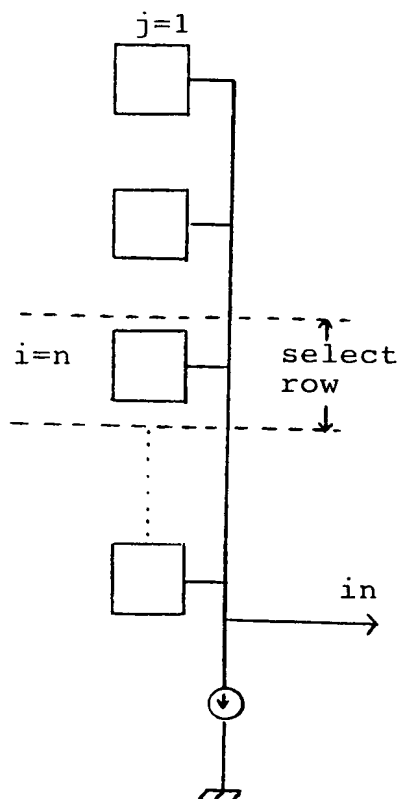
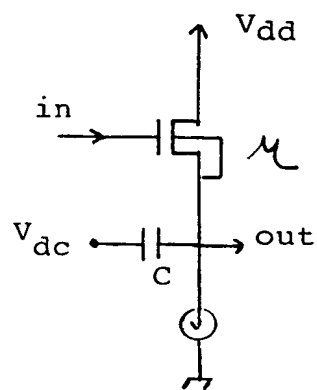
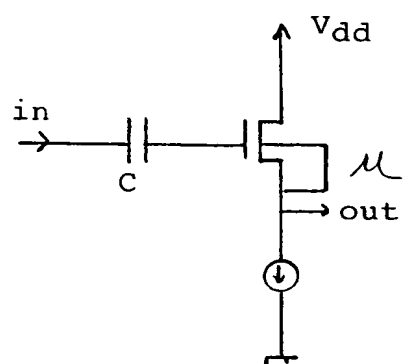


FIG. 4

This Page Blank (uspto)

FIG. 5aFIG. 5bFIG. 5c

This Page Blank (uspto)

5/6

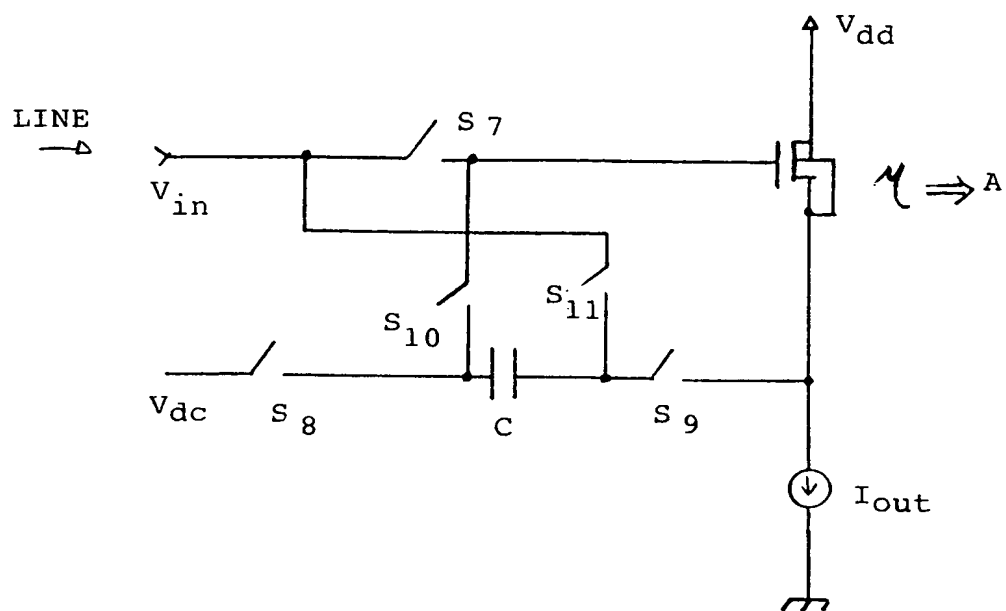


FIG. 6

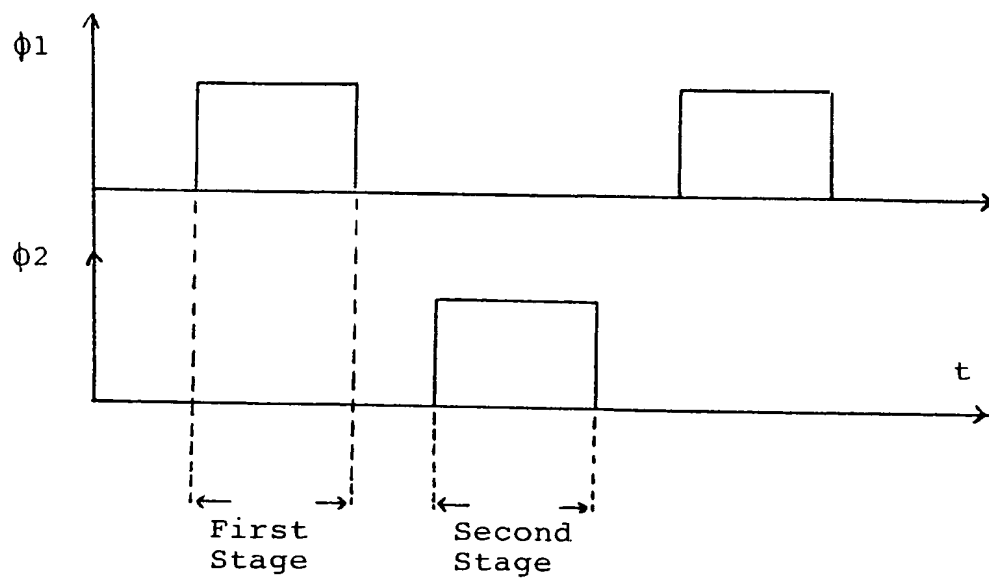


FIG. 7

*This Page Blank (uspto)*

6/6

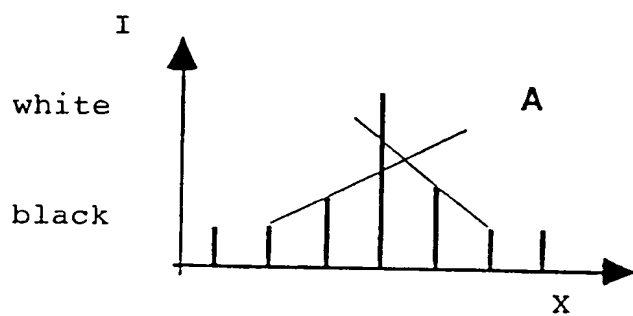


FIG. 8a

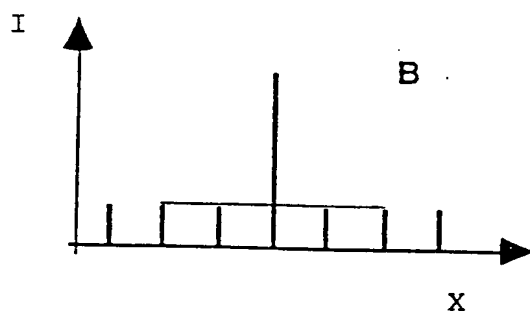


FIG. 8b

This Page Blank (uspto)



# INTERNATIONAL SEARCH REPORT

Intern: 1st Application No

PCT/BE 98/00139

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H04N3/15 H04N5/217

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 773 669 A (IMEC INTER UNI MICRO ELECTR) 14 May 1997 see column 4, line 15 - line 39 see column 7, line 19 - line 30 ---	5,9
X	US 5 321 528 A (NAKAMURA KENICHI) 14 June 1994 see column 3, line 56 - column 4, line 53; claims 1-4 ---	5,9
X	MARTIN W J ET AL: "DYNAMIC OFFSET NULL" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 23, no. 9, February 1981, page 4195/4196 XP002052268 see the whole document --- -/--	5,9



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

13 November 1998

Date of mailing of the international search report

18/12/1998

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Bequet, T

This Page Blank (uspto)

# INTERNATIONAL SEARCH REPORT

Interi      nal Application No  
PCT/BE 98/00139

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 260 954 A (CANON KK) 23 March 1988 see column 13, line 62 - column 14, line 17; figure 10	3-5,7
A	-----	1,6
A	EP 0 481 373 A (SONY CORP) 22 April 1992 see column 4, line 31 - line 52; figure 1 -----	1,6

This Page Blank (uspto)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/BE 98/00139

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0773669	A	14-05-1997	NONE	
US 5321528	A	14-06-1994	JP 4207564 A	29-07-1992
			CA 2056667 A	31-05-1992
			DE 69124347 D	06-03-1997
			DE 69124347 T	28-05-1997
			EP 0488674 A	03-06-1992
EP 0260954	A	23-03-1988	JP 2505768 B	12-06-1996
			JP 63076583 A	06-04-1988
			JP 8004127 B	17-01-1996
			JP 63086471 A	16-04-1988
			JP 2510543 B	26-06-1996
			JP 63152280 A	24-06-1988
			JP 8015321 B	14-02-1996
			JP 63152281 A	24-06-1988
			DE 3752018 D	20-03-1997
			DE 3752018 T	12-06-1997
			EP 0741493 A	06-11-1996
			US 4914519 A	03-04-1990
			US 5737016 A	07-04-1998
			US 5331421 A	19-07-1994
			US 5771070 A	23-06-1998
			US 5311320 A	10-05-1994
EP 0481373	A	22-04-1992	JP 4154282 A	27-05-1992
			DE 69116975 D	21-03-1996
			DE 69116975 T	12-09-1996
			US 5187583 A	16-02-1993

This Page Blank (uspto)